United Nations Environment Programme

Distr.
LIMITED

UNEP/WG.7/11
1st February 1977

Original: ENGLISH

UNEP Meeting of experts designated by Governments, Intergovernmental and Non-Governmental Organizations on the Ozone Layer

Washington, D.C., 1-9 March 1977

# A Report to UNEP on Stratospheric and Ozone Research Activities in Canada

Presented by
The Government of Canada

INDEX

1. Background of Stratospheric Ozone Research in Canada.

2. Survey of Current Research Activities

   2.1 Atmospheric Measurements

   2.2 Stratospheric Monitoring

   2.3 Laboratory Studies

   2.4 Modelling Studies

   2.5 Related Research Projects

3. Future Plans in Stratospheric Ozone Layer Research.

1. Background of Stratospheric Ozone Research in Canada

The recent work that has been done in Canada in response to concern about anthropogenic modification to the stratospheric ozone content has developed from an extensive prior Canadian involvement in ozone research. Ozone monitoring, related stratospheric measurements and laboratory photochemical studies, photochemical modelling and atmospheric data analysis had all been in progress for many years before 1970 when the supersonic aircraft/ozone question was first raised.

Ozone monitoring at the five stations of the Canadian Dobson network has been in continuous operation since 1958 and the ozonesonde network since 1965. Also the Canadian government has run the World Ozone Data Centre (on behalf of WMO) since its inaguration in 1964. Development of a modern standard replacement for the Dobson spectrophotometer was started at the University of Toronto in 1968 by Brewer et al.

In the early sixties the aircraft and balloon measurement programme run by the Canadian Armament Research and Development Establishment (CARDE) accumulated a large data bank of stratospheric infrared spectral measurements which continues to yield useful data on several trace constituents (i.e. Lowe and McKinnon- 1972). Key measurements of the ozone-producing solar ultraviolet flux were made by the University of Toronto group of Brewer and Wilson in 1965 and high altitude ozone concentrations were measured by Evans and Llewellyn in 1970 at the University of Saskatchewan.

Laboratory studies relating to atmospheric ozone photochemistry were pursued by several groups including those at York University, the National Research Council and at CARDE.

Photochemistry models were developed by Hampson in 1966 at CARDE and also, primarily for the upper atmosphere, by Gattinger in 1968 at the National Research Council. Models which incorporated the combined effects of photochemistry and atmospheric transport (two and three dimensional) were constructed by the McGill Arctic Meteorological Research Group which had done extensive analysis of stratospheric motions in relation to ozone (Boville and Hare in cooperation with Godson - 1961).

By the late sixties it was evident that the photochemical schemes then in use (based on oxygen and hydrogen chemistry) would not satisfactorily explain several aspects of the natural behavior of atmospheric ozone. This had been demonstrated by Brewer and Wilson in 1968, and was implicit in the work of Schiff in 1969 and Hampson in 1966 among others. The situation improved with the discovery in 1969 of the dominance of nitrogen chemistry in ozone reduction. Moreover, since 1970, the overall aim has been to predict the effects of anthropogenic modification and consequently the required precision in the whole field has been greatly increased.

During the early seventies the Atmospheric Environment Service (AES), which is the government's lead agency in stratospheric research, had greatly strengthened its expertise in the area largely by recruitment from the Canadian university community. As a result it was then ready to mount an accelerated research programme, which includes in-house research and support of university and industry research projects, and to move in collaboration with other national

and international agencies to meet the challenge of evaluating the new threats to the ozone layer.

General guidance to the AES is provided by an "Advisory Committee on Stratospheric Pollution" which has met twice yearly since 1973. The committee comprises a wide cross-section of government, university and industry scientists who are involved in various aspects of stratospheric research. The committee also, in conjunction with the AES, serves to coordinate overall research in this area.

## 2. Survey of Current Research Activities

Progress in stratospheric research must be based on the combination of laboratory investigations of relevant atmospheric photochemistry, atmospheric modelling of the laboratory data and the testing of models against atmospheric measurements. Only then can the models be used with any confidence to project the future effects of man's activities on the ozone layer.

### 2.1 Atmospheric Measurements

The verification of models against measurements of stratosphere composition and transport is both extremely important and at the same time, very difficult due to the advanced instrumentation required to detect very small amounts of the important trace gases.

The AES Stratospheric Balloon Measurements Project is a multiple experiment balloon payload designed to make simultaneous measurements of key stratospheric trace gases important in the photochemical balance of the ozone layer. The 1974 experiment was flown at 35 km to study the nitrogen chemistry of the stratosphere by making simultaneous measurements of $HNO_3$, $NO_2$, NO, $O_3$ and temperature in conjunction with solar ultraviolet flux measurements. In the program, half of the twelve experiments were conducted by AES scientists and half by Canadian university scientists. Payload engineering and field support of Project STRATOPROBE I (Table 1) were provided by Canadian industry (SED Systems Ltd.).

In the 1975 program, experiments to measure freons, HCl, HF and ClO were incorporated to supplement the measurements of nitrogen chemistry constituents. These new experiments are designed to evaluate the presence of chlorine compounds of natural and anthropogenic origin. In the STRATOPROBE II series, separate flights of the nitrogen chemistry (Table 2) and chlorine chemistry (Table 3) payloads were made.

In 1976, two flights of a combined payload to measure both chlorine and nitrogen chemistry were flown from Yorkton in August. The experiment complement, the experimenters and affiliations involved in the STRATOPROBE III Project are described in Table 4. The AES balloon project is coordinated by W.F.J. Evans, J.B. Kerr and D.I. Wardle of the Atmospheric Environment Service.

In addition to the STRATOPROBE Project, there are a number of other related stratospheric measurement activities, most of them at universities. These include other balloon experiments as well as ground based aircraft and rocket measurements. A listing of these experimental activities is given in Table 5 which also indicates the location and personnel involved.

TABLE 1

The 1974 AES balloon Project: STRATOPROBE I

The Nitrogen Chemistry Experiment

| EXPERIMENT | CONSTITUENTS | EXPERIMENTERS | ORGANIZATION |
|---|---|---|---|
| *SOLAR ABSORPTION* | | | |
| Scanning Solar Radiometer | $H_2O$, $O_3$, $N_2O$ | W. Evans, S. Bain | AES |
| $NO_2$ Spectrophotometer | $HO_2$, $O_3$ | A. Brewer, J. Kerr, T. McElroy | U of Toronto, AES |
| $NO_2$ Scanning Photometer | $NO_2$ | D. Wardle | AES |
| U.V. Flux Spectrometer | U.V. Flux $O_3$ | D. McEwen | U. of Sask. |
| *EMISSION* | | | |
| $HNO_3$ | $HNO_3$ | W. Evans, C. Lin | AES |
| Scanning Emission Radiometer | $H_2O$, $O_3$ | W. Evans, C. Midwinter | AES |
| Far I.R. Michelson | $O_3$, $H_2O$, $HNO_3$ | T. Clark, D. Kendall | U. of Calgary |
| I.R. Spectrometer | OH, $O_2(^1\Delta)$ | E. Llewellyn | U. of Sask. |
| *SAMPLING* | | | |
| NO Snooper | NO | H. Schiff, B. Ridley | York U. |
| $O_3$ Sampler | $O_3$ | R. Olafson, J. Kerr | AES |
| Ozonesonde | P, T, $O_3$, $H_2O$ | | AES |

TABLE 2

STRATOPROBE II

1975 Chlorine Payload Configuration Experiments

| EXPERIMENT | CONSTITUENTS | EXPERIMENTERS | ORGANIZATION |
|---|---|---|---|
| *SOLAR ABSORPTION* | | | |
| Gaspec | HCl, NO | H. Zwick, R. Wiens | Barringer |
| Michelson Interferometer | HCl, NO, $NO_2$, $CH_4$ | H. Buijs | Bomem |
| $NO_2$ Spectrophotometer | $NO_2$ | T. McElroy | AES |
| ClO Spectrophotometer | ClO | J. Kerr | AES |
| U.V. Scanning Spectrometer | $O_3$ | D. McEwen | U. of Sask. |
| *SAMPLING* | | | |
| Nitric Oxide Snooper | NO | B. Ridley, H. Schiff | York University |
| Ozone Chemiluminescent Sampler | $O_3$ | R. Olafson, T. McElroy | AES |
| Modified Ozonesonde | $O_3$ | R. Olafson | AES |
| Whole Air Sampler Spheres | F11, F12, $CCl_4$ | H. Schiff, T. Thompson | York U.; NOAA |
| *SKY RADIATION* | | | |
| Scattering Spectrometer | ClO, OH | D. Wardle | AES |
| 6 to 14μ Scanning Radiometer | $HNO_3$, $O_3$, $N_2O_5$ | W. Evans | AES |
| 11μ Nitric Acid Radiometer | $HNO_3$ | W. Evans, R. O'Brien | AES |

TABLE 3

STRATOPROBE II

1975 Nitrogen Payload Configuration Experiments

| EXPERIMENT | CONSTITUENTS | EXPERIMENTERS | ORGANIZATION |
|---|---|---|---|
| *SOLAR ABSORPTION* | | | |
| Gaspec | HCl, NO | H. Zwick, R. Wiens | Barringer |
| Michelson Interferometer | HCl, NO, $NO_2$, $CH_4$ | H. Buijs, G. Vail | Bomem |
| $NO_2$ Spectrophotometer | $NO_2$ | T. McElroy | AES |
| $NO_2$ Scanning Photometer | $NO_2$ | D. Wardle | AES |
| U.V. Scanning Spectrometer | $O_3$ | D. McEwen | U. of Sask. |
| *SAMPLING* | | | |
| Nitric Oxide Snooper | NO | B. Ridley, H. Schiff | York U. |
| Ozone Chemiluminescent Sampler | $O_3$ | R. Olafson | AES |
| Modified Ozonesonde | $O_3$ | R. Olafson, T. McElroy | AES |
| *SKY RADIATION* | | | |
| IR Spectrometer | OH*, $O_2(^1\Delta)$ | E. Llewellyn | U. of Sask. |
| 6 to 14$\mu$ Scanning Radiometer | $HNO_3$, $O_3$, $N_2O_5$ | W. Evans, R. O'Brien | AES |
| Nitric Acid Radiometer | $HNO_3$ | W. Evans, R. O'Brien | AES |
| Far IR Michelson Interferometer | $O_3$, $H_2O$, $HNO_3$, $N_2O$ | T. Clark | U. of Calgary |

TABLE 4

STRATOPROBE III

1976 Chlorine-Nitrogen Payload Experiments

| EXPERIMENT | CONSTITUENTS | EXPERIMENTERS | ORGANIZATION |
|---|---|---|---|
| *SOLAR ABSORPTION* | | | |
| $NO_2$ Scanning Photometer | $NO_2$ | D. Wardle | AES |
| Michelson Interferometer | HCl, HF, $NO_2$, $CH_4$ | H. Fast, H. Buijs | AES; Bomem |
| $NO_2$ Spectrophotometer | $NO_2$ | T. McElroy | AES |
| ClO Spectrophotometer | ClO | J. Kerr | AES |
| U.V. Scanning Spectrophotometer | $O_3$, U.V. spectra | D. McEwen | U. of Sask. |
| U.V. Fluxmeter | U.V. Flux | J. Williamson | AES |
| *SAMPLING* | | | |
| Nitric Oxide Snooper | NO | B. Ridley, H. Schiff | York University |
| Ozone Chemiluminescent Sampler | $O_3$ | R. Olafson | AES |
| Modified Ozonesonde | $O_3$, T, n(M) | R. Olafson, T. McElroy | AES |
| Whole Air Sampling Spheres | F11, F12, $CCl_4$, $N_2O$ | B. Ridley, H. Schiff | York University |
| *SKY RADIATION* | | | |
| Scattering Spectrometer | ClO, OH | D. Wardle | AES |
| 5 to 14μ Scanning Radiometer | $HNO_3$, $O_3$, $N_2O_5$, $CH_4$ | W. Evans, R. O'Brien | AES |
| 11μ Nitric Acid Radiometer | $HNO_3$ | W. Evans, R. O'Brien | AES |
| Far I.R. Michelson Interferometer | $O_3$, $H_2O$, HCl, $N_2O$ | T. Clark, D. Kendall | U. of Calgary |

TABLE 5

| MEASUREMENT | EXPERIMENTERS | ORGANIZATION |
|---|---|---|
| Solar Absorption Measurements of HCl, HF with a balloon borne Michelson Interferometer. | H. Buijs | Bomem, Inc. |
| Ground based monitoring of stratospheric gases with a high resolution Michelson Interferometer. | H. Buijs | Laval University |
| Analysis of stratospheric trace gases from CARDE balloon and aircraft. I.R. Data. | R.P. Lowe | U. of Western Ontario |
| Spectrophotometric Measurements of $NO_2$ and $O_3$ from ground and aircraft. | A.W. Brewer, C.T. McElroy, J.B. Kerr | University of Toronto AES |
| Balloon flight measurements of nitric oxide in the stratosphere. | B.A. Ridley, H.I. Schiff | York University |
| Grab sampling of stratospheric air and subsequent laboratory analysis for freons and $N_2O$. | B.A. Ridley, H.I. Schiff | York University |
| High resolution ground based solar spectrum measurements for detection of ClO. | R.W. Nicholls, W. Fabian | York University |
| Balloon measurements of stratospheric constituents by submillimeter interferometer in emission and absorption. | T.A. Clark, et al. | University of Calgary |
| Rocket measurements of water vapour in the stratosphere. | W.F.J. Evans, R. O'Brien | AES |
| Rocket measurements of high altitude ozone from $O_2(^1\Delta)$. | E.J. Llewellyn | U. of Saskatchewan |

## 2.2 Stratospheric Monitoring

Ozone monitoring is important to establish the climatology of ozone and to verify predictions of ozone depletion which should ultimately be detectable as trends in the world total ozone. Current activities in this direction include maintaining and improving the precision of the Dobson network and the ozonesonde network as well as continuing evaluation of satellite BUV ozone data. In order to overcome instrumental and operational deficiencies in the Dobson instrument, a new total ozone spectrometer has been developed and is now in initial stages of commercial production. This is a grating instrument with digital electronics and capable of being highly automated, a feature which should significantly reduce the amount of operator time required for measurements.

TABLE 6

| | | |
|---|---|---|
| Canadian ozone monitoring network. Ozonesondes, Dobson ozone instruments. | R.A. Olafson, A. Asbridge | AES |
| Publication of World Ozone Data. | L. Morrison | AES |
| Satellite BUV Ozone Measurements. | C.L. Mateer | AES |
| Solar Ultraviolet Flux Monitoring in Saskatchewan. | D.J. McEwen | U. of Sask. |
| Development of new network ozone spectrophotometer. | J.B. Kerr, D.I. Wardle, C.T. McElroy (contractor - SED Systems Ltd.) | AES |

## 2.3 Laboratory Studies

These comprise studies of chemical reaction rates and of photo absorption cross-sections; more accurate data is required in both areas for stratospheric modelling. As well, spectroscopic studies are used to parameterize certain detailed absorption processes and to aid spectroscopic measurement of trace constituents in the stratosphere.

TABLE 7

| | | |
|---|---|---|
| Photochemical reactions of atmospheric interest: quenching of $O(^1D)$ by $N_2O$, $O_2$, $N_2$, etc. | H.I. Schiff | York University |
| Spectroscopic studies of stratospheric molecules, spectroscopy of ClO, $O_2$. | R.W. Nicholls, et al. | York University |
| Single particle detection of atmospheric species, photodissociation studies. | J.W. McConkey | U. of Windsor |
| Studies of absorption of infrared radiation by ozone and $NO_2$. | C. Young | U. of New Brunswick |
| Laboratory Studies of Excited Species of Atmospheric Interest: Photolysis of ozone, hydroxyl reactions with freons. | R.J. Cvetanovic | NRC |
| Ultraviolet Absorption Properties of Fluorocarbons. | C. Sandory | U. of Montreal |
| Absorption spectroscopy of ClO. | J.A. Coxon | Dalhousie U. |

## 2.4 Modelling Studies

Models of the natural stratosphere including photochemistry and transport are required to simulate the ozone layer and to project ozone depletions due to anthropogenic increases in $NO_x$ by aircraft and fertilizer usage as well as freon release into the troposphere. Fortunately, modelling work of this type is being carried out in Canada. Models to predict climatic effects of ozone depletion as well as the direct greenhouse effect of freons on the climate are also required for an evaluation of stratospheric pollution problems.

TABLE 8

| | | |
|---|---|---|
| A 2-dimensional photochemical meteorologically interactive steady state model of the stratosphere. A time dependent version is being tested. | R.K.R. Vupputuri | AES |
| One and 2-dimensional time-dependent photochemical models of the ozone layer with parameterized transport. | J.C. McConnell | York University |
| Calculation of stratospheric ultraviolet fluxes. | R.W. Nicholls, M.W. Cann | York University |

TABLE 8 (cont'd)

| | | |
|---|---|---|
| General Circulation Models and Climatic Variation; Effects of Freons on Climate. | G.J. Boer et al | AES |

## 2.5 Related Research Projects

The precursor of the natural destruction process of ozone is nitrous oxide produced by microbiological organisms at the earth's surface. Studies of microbiological production in the soil are complemented by measurements of tropospheric nitrous oxide and of nitrous oxide in the oceans. The flux from the oceans into the atmosphere is at present crucial to the evaluation of the nitrogen fertilizer/oxone problem and is highly uncertain.

Tropospheric measurements of halocarbons bear directly on freon ozone destruction and continue to be necessary. Report studies of the effects of stratospheric ozone reduction are also in progress.

TABLE 9

| | | |
|---|---|---|
| Tropospheric Measurements of Freons. | L. Elias | NRC |
| Tropospheric measurements of $N_2O$. | J.W. McKenny | U. of Windsor |
| Microbiological Studies of Nitrous Oxide and nitrogen fertilizers. | R. Knowles | Macdonald College of McGill U. |
| Measurements of $N_2O$ content in oceans. | T. Yoshinari | Macdonald College |
| Environmental Studies of Stratospheric Pollution. | F.K. Hare | U. of Toronto |
| Survey Report Studies of Freon Ozone Depletion. | R.E. Munn | AES |

3. Future Plans in Stratospheric Ozone Layer Research

1. To continue a broad program of research and development on the ozone layer in government, industry and universities.

2. To continue to operate the Canadian ozone network. Edmonton, Resolute, Churchill, Goose Bay and Toronto have Dobson instruments. Ozonesondes are flown each Wednesday (except Toronto).

3. To continue publication of World Ozone Data.

4. To test the new ozone spectrophotometer under operating conditions and carry out intercomparison tests with a view to replacing the Dobson instruments in the Canadian network.

5. To continue one and two dimensional modelling of the ozone layer and the effects of stratospheric pollution.

6. To conduct flights of Project Stratoprobe in 1977 to measure the chlorine-nitrogen chemistry of the ozone layer.

7. To participate in international programs of research and monitoring and in coordinated intercomparisons of experimental measurements of trace stratospheric constituents.

Prepared by Dr. B.W. Boville and Dr. W.F.J. Evans
Atmospheric Environment Service, Toronto, CANADA.